MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 3, 2015/2016

ETM 7176 – OPTICAL COMMUNICATION SYSTEMS

M.Eng. (Telecommunication)

30 MAY 2016
8.00 p.m – 11.00 p.m
(3 Hours)

INSTRUCTION TO STUDENT

1. This Question paper consists of **7** pages including cover page with **4** Questions only.

2. Attempt **ALL** questions. Each question carries different marks and the distribution of the marks for each question is given.

3. Please print all your answers in the Answer Booklet provided. Please number your answers clearly.

Question 1

(a) Describe differences between step index multimode optical fiber and graded index multimode optical fiber.

[6 marks]

(b) A certain optical fiber has an attenuation of 0.6 dB/km at 1300 nm and 0.3 dB/km at 1550 nm. Suppose the following two optical signals are launched simultaneously in the fiber: an optical power of 150 μW at 1300 nm and an optical power of 100 μW at 1550 nm. What are the power levels in μW of these two signals at 8 km.

[4 marks]

(c) A step-index single-mode fiber exhibits material dispersion of 6 ps/nm/km at an operating wavelength of 1.55 μm. Assume that n_1=1.45 and Δ=0.5%. Calculate the diameter of the core needed to make the total dispersion of the fiber zero at this wavelength. Given that the waveguide dispersion can be found using the following equation

$$D_w = -\frac{n_2\Delta}{c\lambda}\left[0.080 + 0.549(2.834 - V)^2\right]$$

[10 marks]

(d) Stimulated Raman Scattering (SRS) occurs as a result of interaction between the light and molecular vibrations of the medium (glass in the case of optical fiber). With the aid of a diagram, show how SRS can distort wavelength division multiplexing (WDM) signals in time and frequency domain.

[5 marks]

Continued...

Question 2

(a) Using block diagram, briefly describe the two types of modulation technique to convert electrical signals to optical beam stream through intensity modulation.

[8 marks]

(b) Briefly describe 4 considerations that must be taken into account when choosing an optical source for optical fiber communication system.

[3 marks]

(c) A *p-i-n* photodiode, on average, generates one electron-hole pair per two incident photons at a wavelength of 0.85 μm. Assuming all the photo-generated electrons are collected, calculate the followings:

(i) The quantum efficiency of the diode.

[1 marks]

(ii) The maximum possible band gap energy (in eV) of the semiconductor, assuming the incident wavelength to be a long-wavelength cut-off.

[4 marks]

(iii) The mean output photocurrent when the incident optical power is 10 μW.

[4 marks]

(d) For an Erbium Doped Fiber Amplifier (EDFA) power amplifier that produces output power of 27 dBm with input power level of 2 dBm at 1542 nm.

(i) Find the amplifier gain.

[2 marks]

(ii) What is the minimum pump power required?

[3 marks]

Continued...

Question 3

(a) (i) Discuss the relation of the laser linewidth associated with the transmitter laser and the local oscillator to *phase noise* in coherent communication systems.

[4 marks]

(ii) Why is the sensitivity to phase fluctuations reduced for asynchronous heterodyne receivers?

[2 marks]

(iii) Discuss the effects of adjusting bandpass filter linewidth at the receiver in addressing the phase noise impact.

[3 marks]

(b) How to utilize a nonlinear optical-loop mirror (NOLM) for demultiplexing optical time-division multiplexing (OTDM) signals? Support your answer with suitable schematic and proper labels.

[8 marks]

(c) Dry fibres have acceptable losses over a spectral region extending from 1.3 to 1.6 μm. Estimate the capacity of a WDM system covering this entire region using 40-Gb/s channels spaced apart by 50 GHz.

[4 marks]

(d) The C and L spectral bands cover a wavelength range from 1.53 to 1.61 μm. How many channels can be transmitted through a WDM system covering these two bands when the channel spacing is 25 GHz? What is the effective bit rate-distance product when a WDM signal covering the two bands using 10-Gb/s channels is transmitted over 2000 km?

[4 marks]

Continued...

Question 4

(a) The definition of the dispersion length, L_D, is given by,

$$L_D = \frac{\tau^2}{|\beta_2|}$$

where τ is the pulse width, and the β_2 is the second-order dispersion coefficient. Starting with the above definition, derive the relationship between the *maximum* transmission bit rate, B_T and the normalized soliton spacing, $2q_0$, for soliton propagation when the amplifier spacing, L_A is very much smaller than the dispersion length (i.e. $L_A << L_D$). Note that $2q_0$ is the ratio of the bit period to the pulse width.

[8 marks]

(b) A 40-Gb/s soliton system is operating at 1.55 μm using fibres with a chromatic dispersion D = 2 ps/(nm-km). The effective core area A_{eff} of the fibre is 50 μm^2. The nonlinear parameter is given by, $\gamma = (2\pi n_2)/(\lambda A_{eff})$, where $n_2 = 2.6\times10^{-20}$ m^2/W is the nonlinear-index coefficient. The second-order dispersion coefficient is given by, $\beta_2 = -(\lambda^2 D)/(2\pi c)$, where λ is the light wavelength and c is the speed of light in vacuum. Calculate the peak power required for fundamental solitons with a normalized soliton spacing, $2q_0 = 8$.

[9 marks]

Continued...

(c) An optical source produces a transmitter beam of angle θ_b and a power P_S transmitted over a distance Z, as shown in Figure Q4.

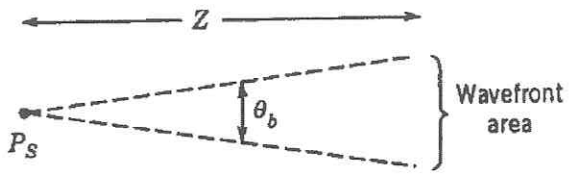

Figure Q4

(i) Derive the corresponding field intensity inside the beam at a distance Z.

[4 marks]

(ii) Illustrate the beam propagation in a clear-air channel with turbulence layer that has bigger dimension than the beamfront area.

[4 marks]

Continued...

Appendix A

Physical Constants and Units

Constant	Symbol	Value (mks units)
Speed of light in vacuum	c	3×10^{8} m/s
Electron charge	q	1.602×10^{-19} C
Boltzmann's constant	k_B	1.38×10^{-23} J/K
Permittivity of free space	ε_0	8.8542×10^{-12} F/m
Permeability of free space	μ_0	$4\pi \times 10^{-7}$ N/A^2
Electron volt	eV	1 eV = 1.602×10^{-19} J
Planck's constant	h	6.626×10^{-34} J·s

End of paper